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16. Abstract (Limit: 200 words)

The Environmental Protection Agency (EPA) is currently investigating the amount and the frequency of misfueling and its effect on motor vheicle exhaust emissions. This report summarizes four different prgrams, three of which have been completed and one which is still under way. Included in this report are the effects of tampering on exhaust emissions and on emission control components, the comparison between low and high altitude, the effects of continous misfueling and the frequency of misfueling.

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Exhaust Emissions
Inspection
Maintenance
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Nitrogen Oxides

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Misfueling
Tampering

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Investigations Into The Emissions Effects of Vehicle Misfueling

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Presented To:

The Tenth North American Motor Vehicle Emission Control Conference

State and Territorial Air Pollution Program Administrators

New York, New York
April 2, 1984

Investigations into the Emissions Effects of Vehicle Misfueling

So far this afternoon, we have heard about the extent of tampering and misfueling around the country. These statistics are dismaying when one envisions the loss in emission control that results. Our role, in the Emission Control Technology Division, is to quantify that loss of control, and our most recent projects have focused on the effects of vehicle misfueling.

In our test programs, we are investigating how both the amount and the frequency of misfueling affect emissions. There are four different programs, three of which have been completed and one which is still under way. The first program, which we call "ATL Continuous," subjected five 1981 and 1982 model year vehicles to ten successive tanks of leaded fuel. The program was conducted by Automotive Testing Laboratories in Liberty, Ohio, and mileage was accumulated rapidly on the vehicles at the ATL Ohio test track. The second, which we call "ATL Frequent," subjected six 1981 and 1982 model year vehicles to 12 tanks of leaded fuel in cycles where one out of two tanks was leaded. The last two test programs, called "ATL Intermittent" and "EPA Intermittent"

focused on the effects of using one tank of leaded fuel out of every four to five tanks of fuel consumed. At ATL, mileage was accumulated quickly on the test track, but the cars were operated on a variable driving cycle intended to simulate real world driving, averaging approximately 30 miles per hour. In the EPA program, mileage was accumulated through normal driving practices. We accomplished this by utilizing the fleet of loaner vehicles given to owners who participate in the emission factor program at the Motor Vehicle Emission Laboratory in Ann Arbor. The EPA program is still under way.

This slide shows the effect of misfueling on the vehicles in the ATL Continuous study. The first bar of each histogram shows the baseline, the second the emission level after ten tanks, and the third the level with the catalyst removed. Although you do not see it in these histograms, emissions were measured after each two tanks of leaded fuel were consumed.

HC emissions increased fairly steadily for all five vehicles, although not to the same degree. In this program, there was a 76% loss of HC conversion efficiency after ten tanks of leaded fuel. Also the HC increases are more dramatic than those for NOx and CO, similar to observations in previous

testing programs. Catalysts are generally more negatively affected by misfueling in their HC conversion efficiency. Later, when we compare the effects of continuous vs. frequent vs. intermittent misfueling we will look only at the HC comparisons.

For the four vehicles with three-way catalysts, NOx emissions rose to nearly double the baseline levels. Once again the rate of increase varied from vehicle to vehicle. After ten tanks, NOx conversion efficiency was reduced by 29%.

The increase in CO emissions is not so dramatic as that for HC, but still the average CO emissions after ten tanks are 2.8 times the baseline levels. Conversion efficiency loss is approximately 45%. The degree of emission increase varied considerably from vehicle to vehicle, however. For example, the CO emission increases of the five vehicles ranged from 10% to 300%. CO emissions increased significantly for only four out of the five vehicles, and often leveled off after a few tanks of leaded fuel, rather than continually increasing.

We noticed a similar, but not so dramatic leveling off of the increase in HC emissions. Hydrocarbon levels increased rapidly with the first four tanks and then rose more slowly. We believe that the emission levels would continue to rise with subsequent misfueling, eventually reaching the catalyst

removed levels. However, these levels were not reached after ten tanks of leaded fuel.

An additional element of the ATL Continuous study was the replacement of the oxygen sensor on the three closed-loop vehicles. This slide shows the HC levels at five different test conditions: baseline, after ten tanks, with the catalyst removed, with a new catalyst installed, and with a new oxygen sensor. It was observed that the main impact of misfueling was on catalyst poisoning, since the emission levels returned to near baseline when new catalysts were installed. With new oxygen sensors, HC and CO decreased further on all three vehicles, but NOx increased on two vehicles. This indicates the poisoned oxygen sensors were sending incorrect signals indicating a richer air-fuel mixture was needed, when it really was not.

With ATL Continuous serving as our focal point, we then varied the testing conditions for comparison purposes. First the five poisoned catalysts and oxygen sensors from ATL were sent to the Colorado Department of Health for testing on matching vehicles at high altitude. The lab in Colorado attempted to obtain vehicles which matched the ATL vehicles in terms of model year, manufacturer, transmission, engine, catalyst, and mileage accumulation. In one case a match was

not possible, so the high altitude comparison is based on only four vehicles. These vehicles were all equipped with three-way catalysts, and three of the four were closed-loop.

The next three slides illustrate the comparison between low and high altitude effects of continuous misfueling. The histograms appear to indicate similar effects at low and high altitude, but a calculation and comparison of emission increases and conversion efficiency losses would indicate a significantly lower effect at high altitude. Frankly, we can think of no reason why this should be the case and are inclined to attribute the difference to car to car variability and small sample sizes. We are, however, looking more closely at the individual test data to see if there is a better explanation. We are comfortable at this point saying, at least, that misfueling at high altitude has no greater adverse effect than at low altitude.

Next we turned to the frequency question. We can envision circumstances where a vehicle would not be habitually misfueled. For instance, there may be only one member of a household who misfuels, and this member may drive the vehicle infrequently. We were also interested in finding out whether operating the vehicle on unleaded fuel for a period of time might restore some or all of the catalyst's conversion efficiency.

As I explained before, we have been conducting four different test programs in which vehicles are misfueled either continuously or one out of two tanks or one out of five tanks. The two intermittent programs are the ones in which the vehicles received the most normal mileage accumulation.

This slide shows the first comparison of the four test programs. Here we are plotting FTP HC emission levels against the number of leaded tanks. A preliminary conclusion might be that the frequency of misfueling is not a factor in the rate of emission increase. We also see a somewhat surprising result in the fact that the vehicles in the frequent misfueling study reach higher HC emission levels than those in the continuous study.

We then decided to look at the comparison by plotting HC emission levels against grams of lead consumed. The grams of lead measure may also be thought of in terms of gallons, since the fuel we used contained very close to one gram of lead per gallon, which is the average of commercially available leaded fuels.

Now we begin to see some difference in the effects of casual vs. habitual misfueling. The continuous and frequent study vehicles reach similar levels and so do those in the two

intermittent studies. The rate of emission increase, however, is definitely lower in the intermittent misfueling programs.

One final measurement of interest is the increase in methane versus non-methane hydrocarbons. As you can see from this slide, there is an increase in methane emissions, about 38%. Non-methane HC emissions, however, increase by 321%. Thus, the effect of misfueling is to cause a sharp rise in reactive hydrocarbons in the atmosphere.

To summarize the conclusions from our ongoing investigation into the emission effects of misfueling catalyst vehicles:

1. Emission levels steadily increase with misfueling such that after ten tanks, HC emissions are over four times the baseline levels; CO emissions nearly three times; NOx emissions nearly twice the baseline levels.

2. Most catalyst deactivation occurs within four tanks of leaded fuel. HC and CO emissions continue to increase with further misfueling, but not to the same degree. After ten tanks, catalysts are not completely deactivated, but only about one-fourth of the original HC control, half the original CO control, and three quarters of the original NOx control remain.

3. There is, as expected, car to car variability in the effect of misfueling, particularly for CO.

4. The primary reason for the emission increase is that the catalyst is poisoned. The oxygen sensor is also affected, but is only responsible for a small portion of the increase.

5. Misfueling at high altitude does not appear to have a greater emission impact than at low altitude.

6. Continuous or habitual misfueling causes emissions to rise at a higher rate than intermittent or casual misfueling.

7. The increase in total hydrocarbons is comprised mostly of non-methane HC.

Before I close this afternoon, I would like to give you a preview of coming attractions. There is a growing interest in finding a short test for catalyst function that can be used in inspection programs which conduct misfueling checks.

It has always been our custom to perform the whole battery of

short emission tests along with the FTP at each test cycle. In the EPA Intermittent test program which is still running we are also exploring the potential of other tests to accurately identify vehicles which exceed FTP emission standards due to misfueling. There is no time left today, and it is a bit premature to draw conclusions, but I just want to give a feeling for the options being investigated.

These include:

Skin temperature measurements at the inlet and outlet of the catalyst to associate catalyst activity with a minimum temperature rise;

Idle and loaded mode tests with a spark plug disconnected to discover if the additional HC burden will cause a misfueled vehicle to fail a short test.

Higher speeds and loads to improve the loaded short test's ability to identify misfueled vehicles;

A short transient test consisting of the first two cycles of Bag 2 of the FTP; and

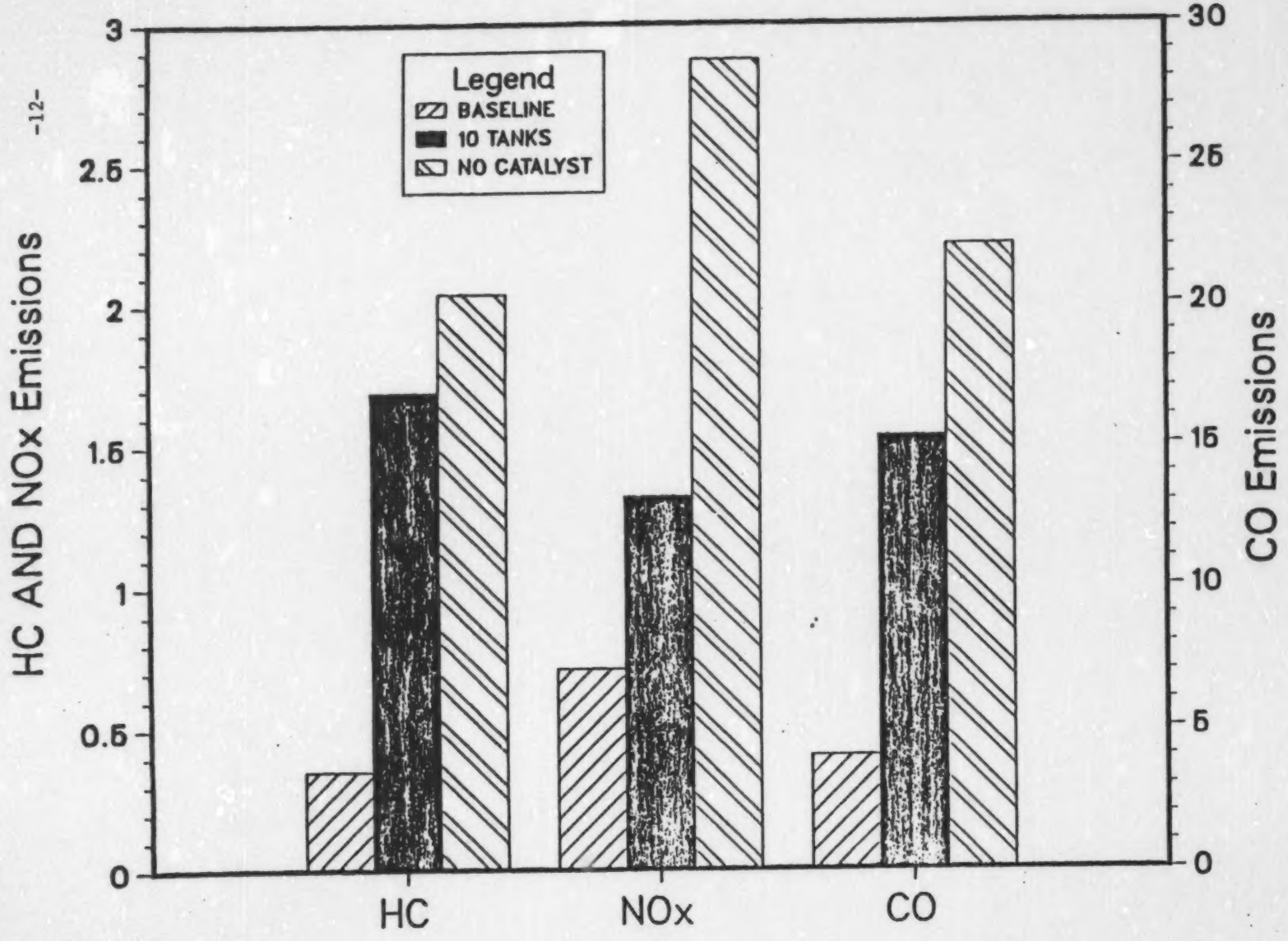
Gamma ray measurements to detect lead accumulation in the catalysts.

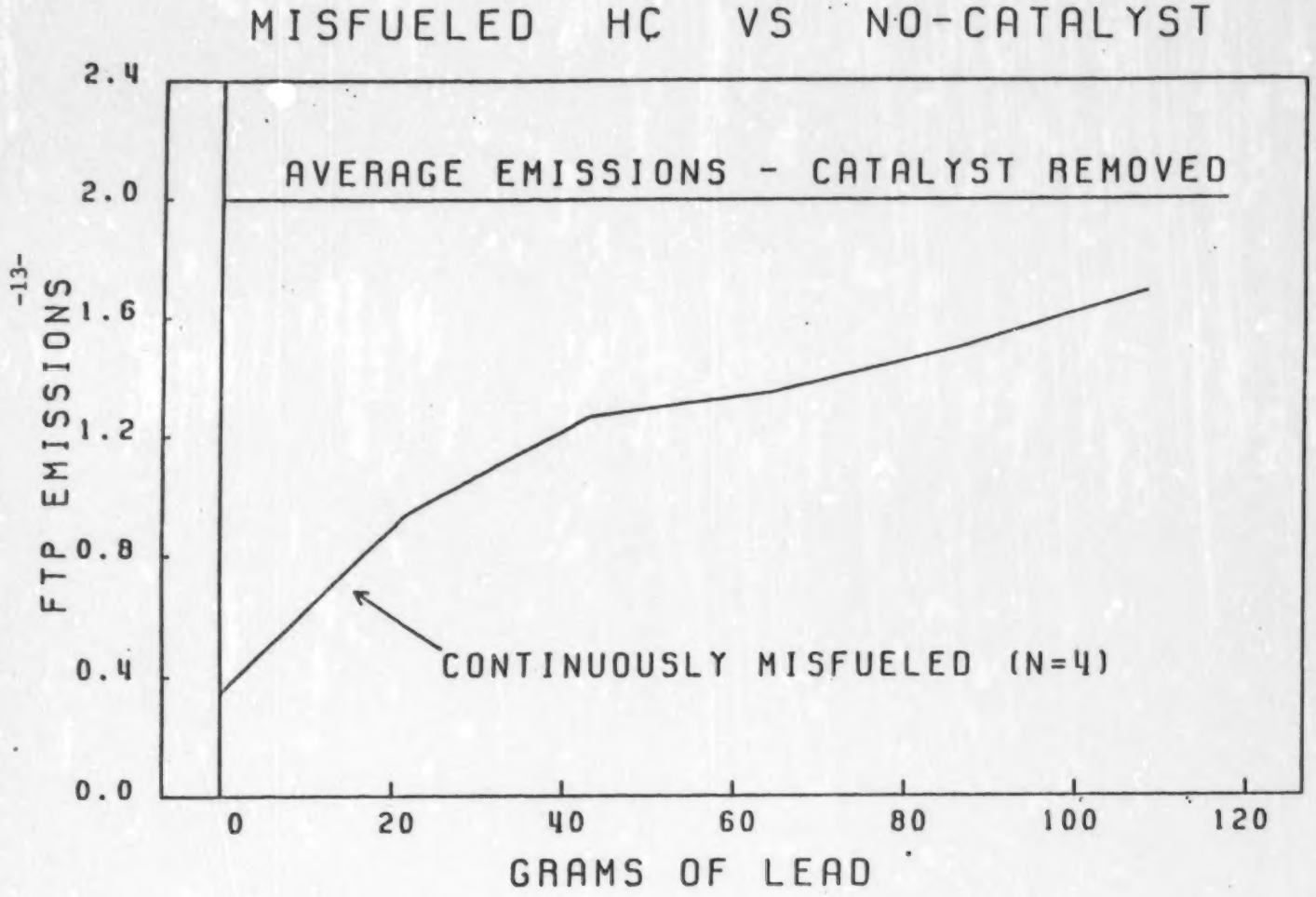
That is the conclusion of my presentation. I would like to thank you for the opportunity to present the results of our studies, and I would be happy to answer any questions you may have.

MISFUELING TEST PROGRAMS

- ATL CONTINUOUS 1:1
- ATL FREQUENT 1:2
- ATL INTERMITTENT 1:5
- EPA INTERMITTENT 1:5

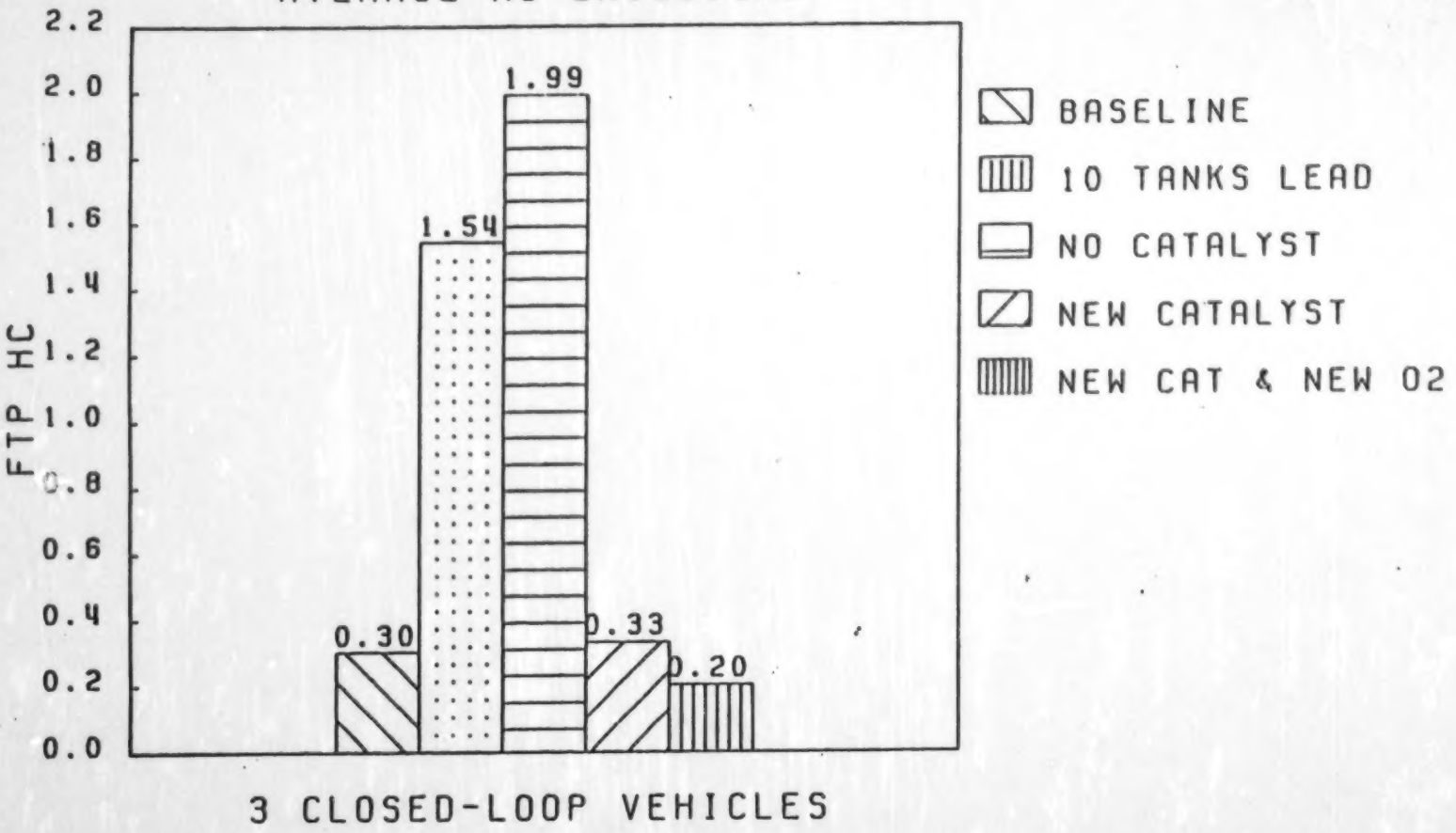
FIVE CONTINUOUSLY MISFUELED CARS

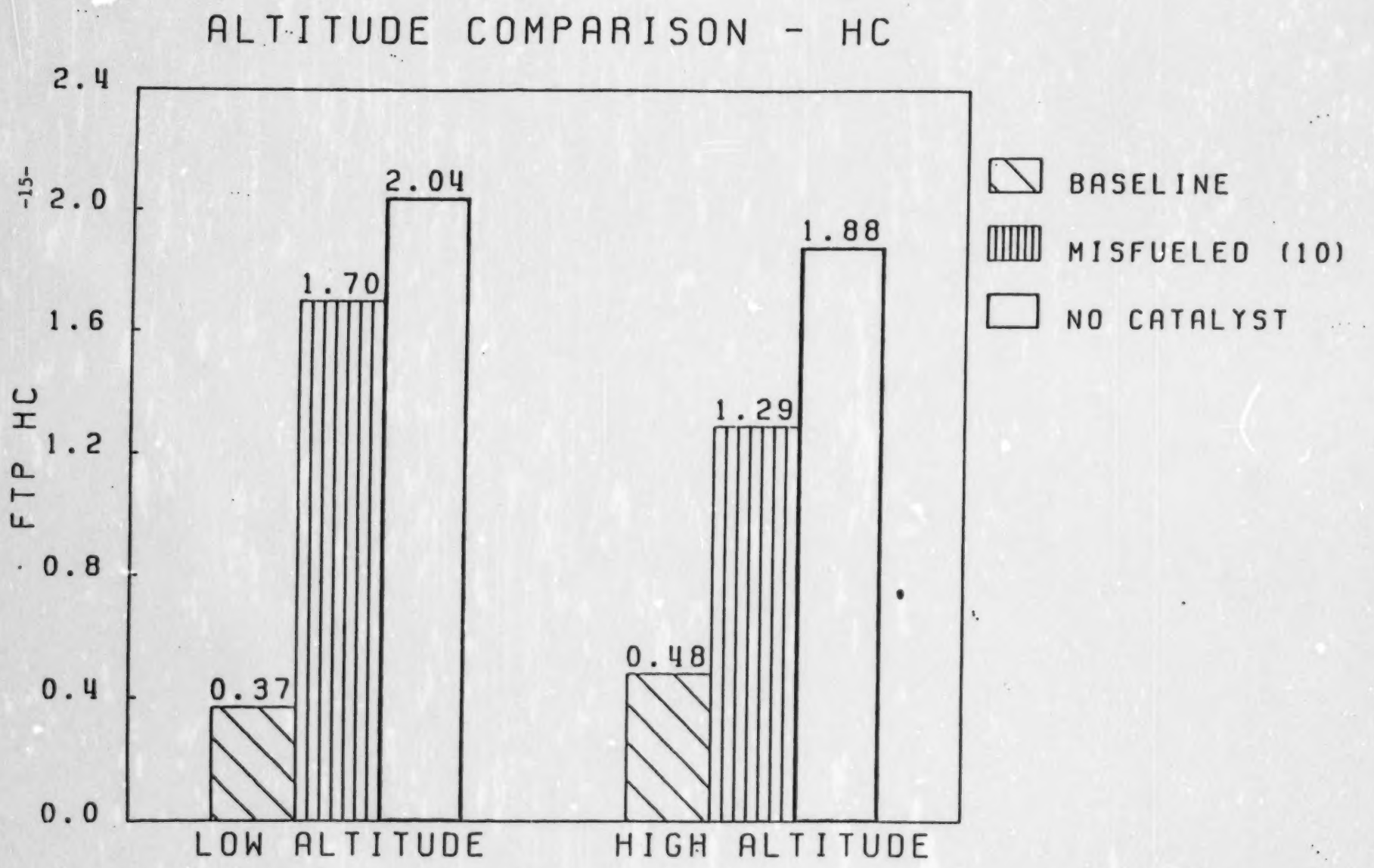


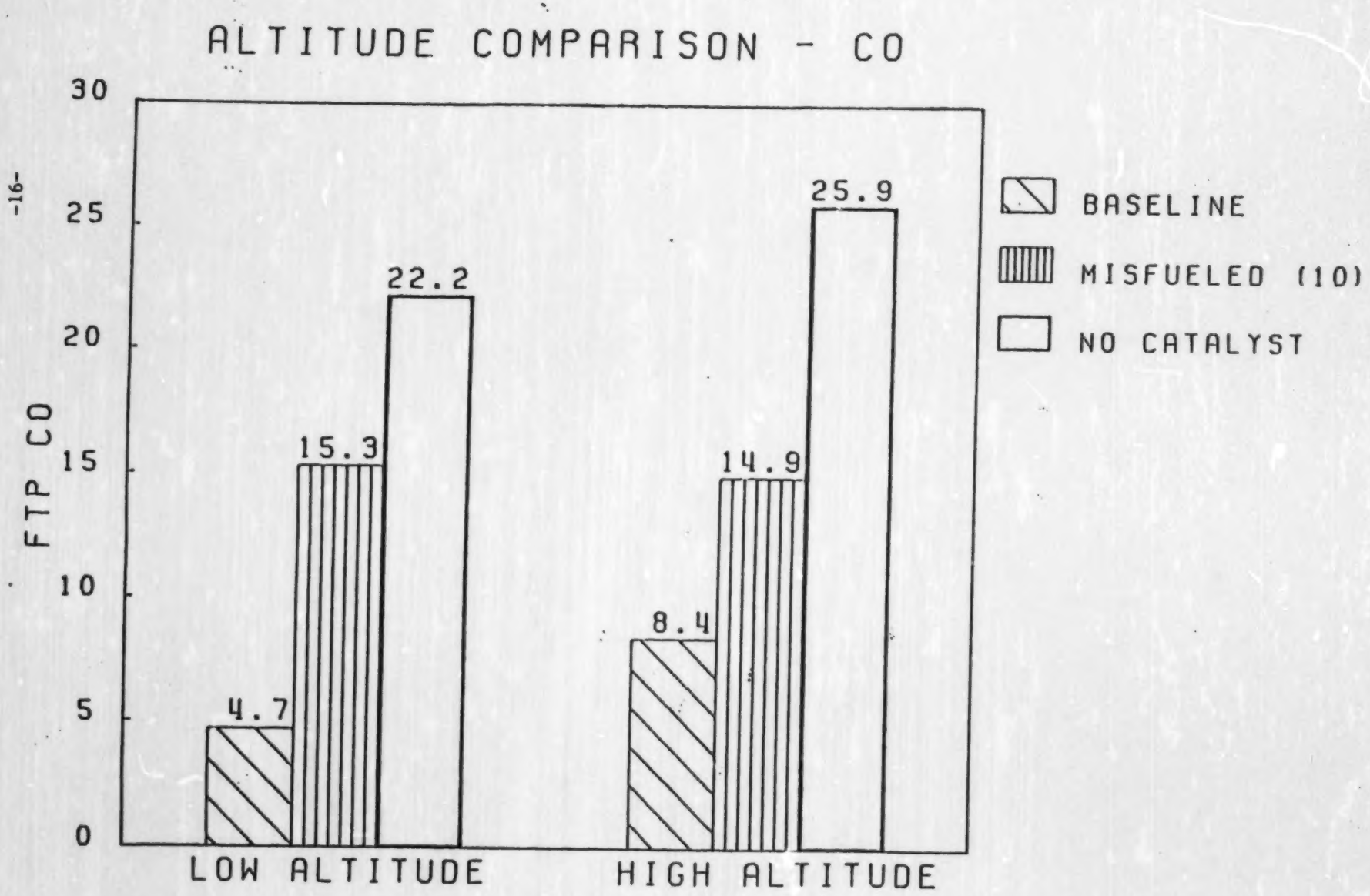

MISFUELED HC VS NO-CATALYST
AVERAGE EMISSIONS - CATALYST REMOVED
CONTINUOUSLY MISFUELED (N=4)
FTP EMISSIONS
2.4
2.0
1.6
1.2
0.8
0.4
0.0
0
20
40
60
80
100
120
GRAMS OF LEAD

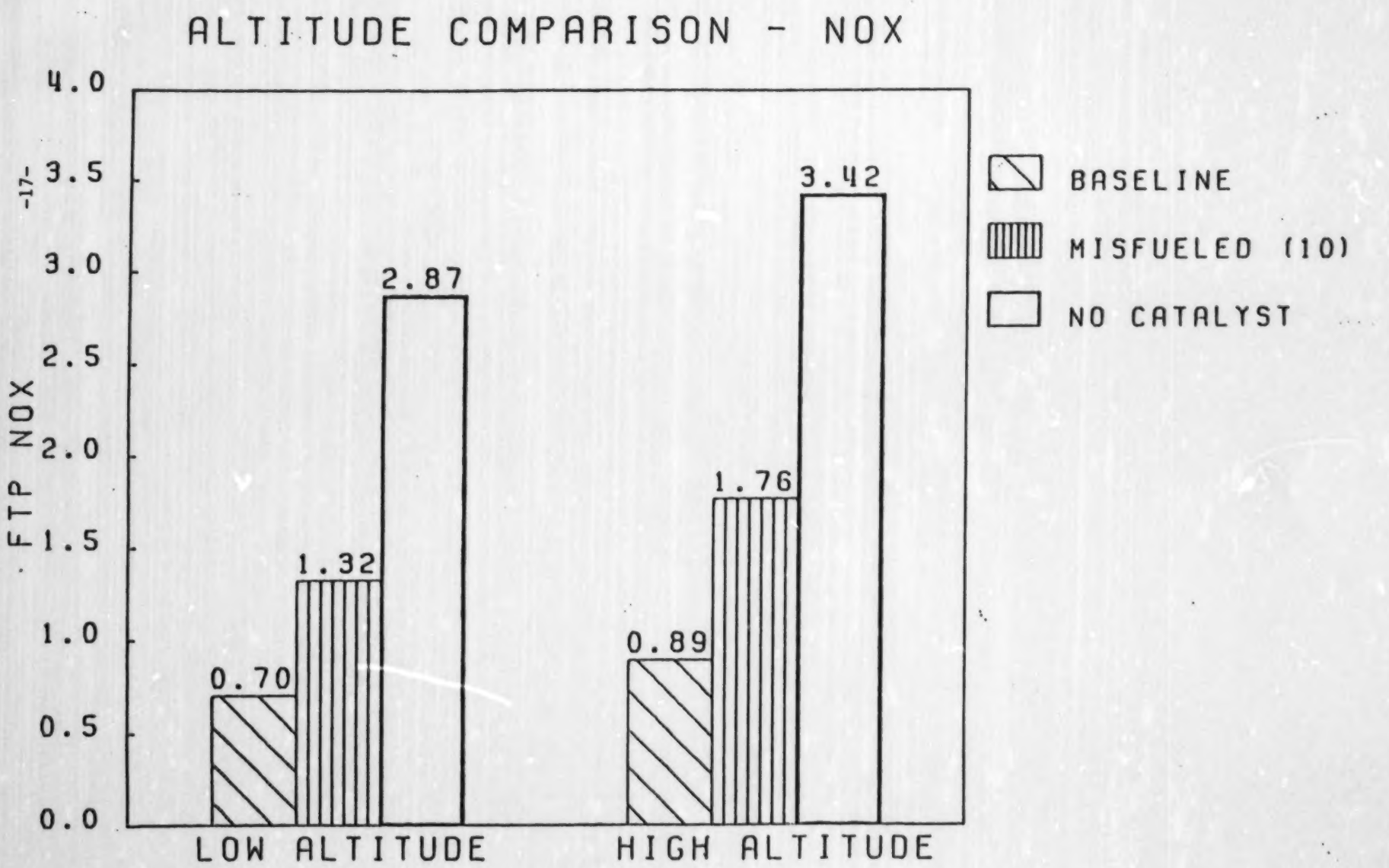
NEW CATALYST AND NEW OXYGEN SENSOR

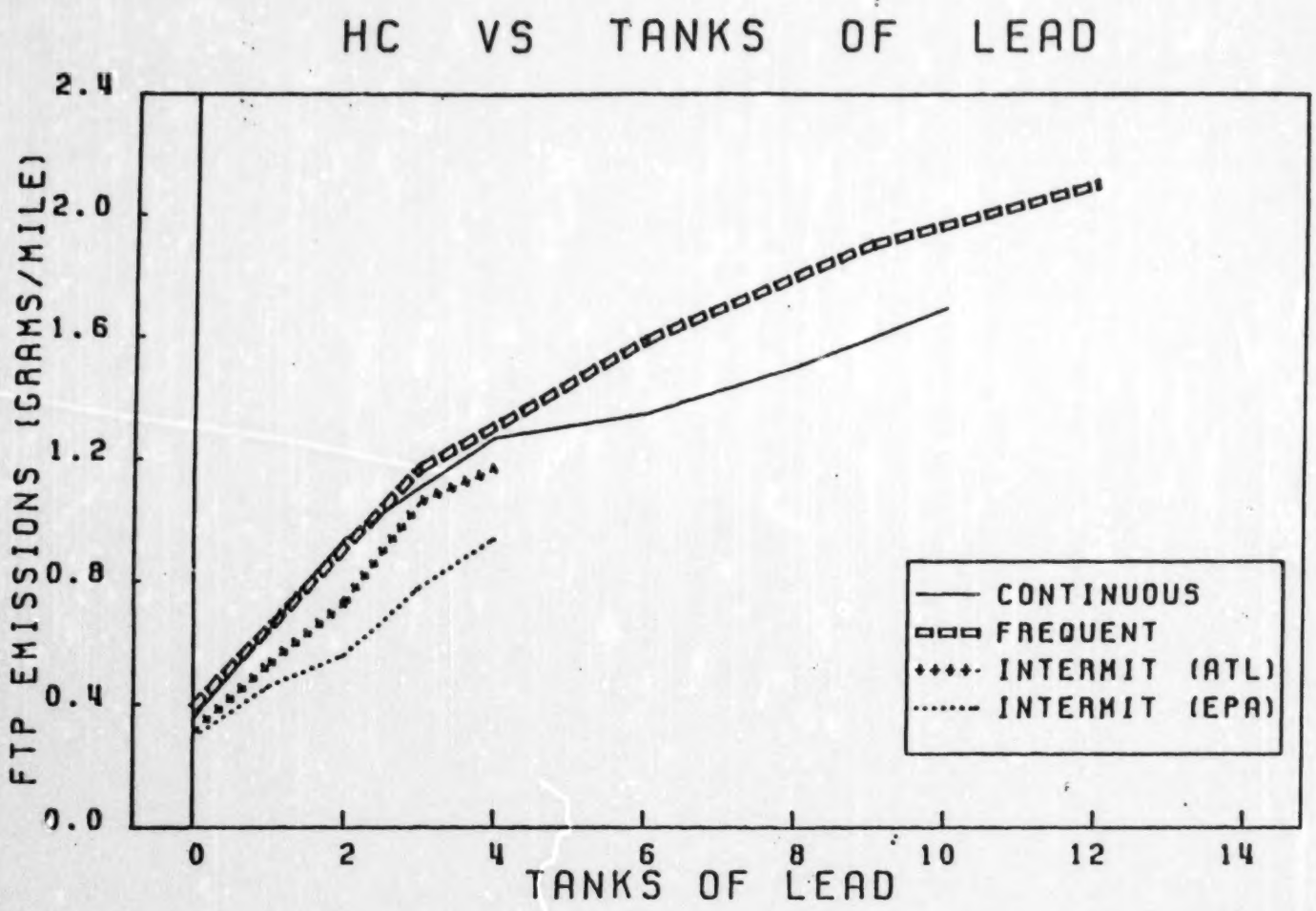
AVERAGE HC EMISSIONS



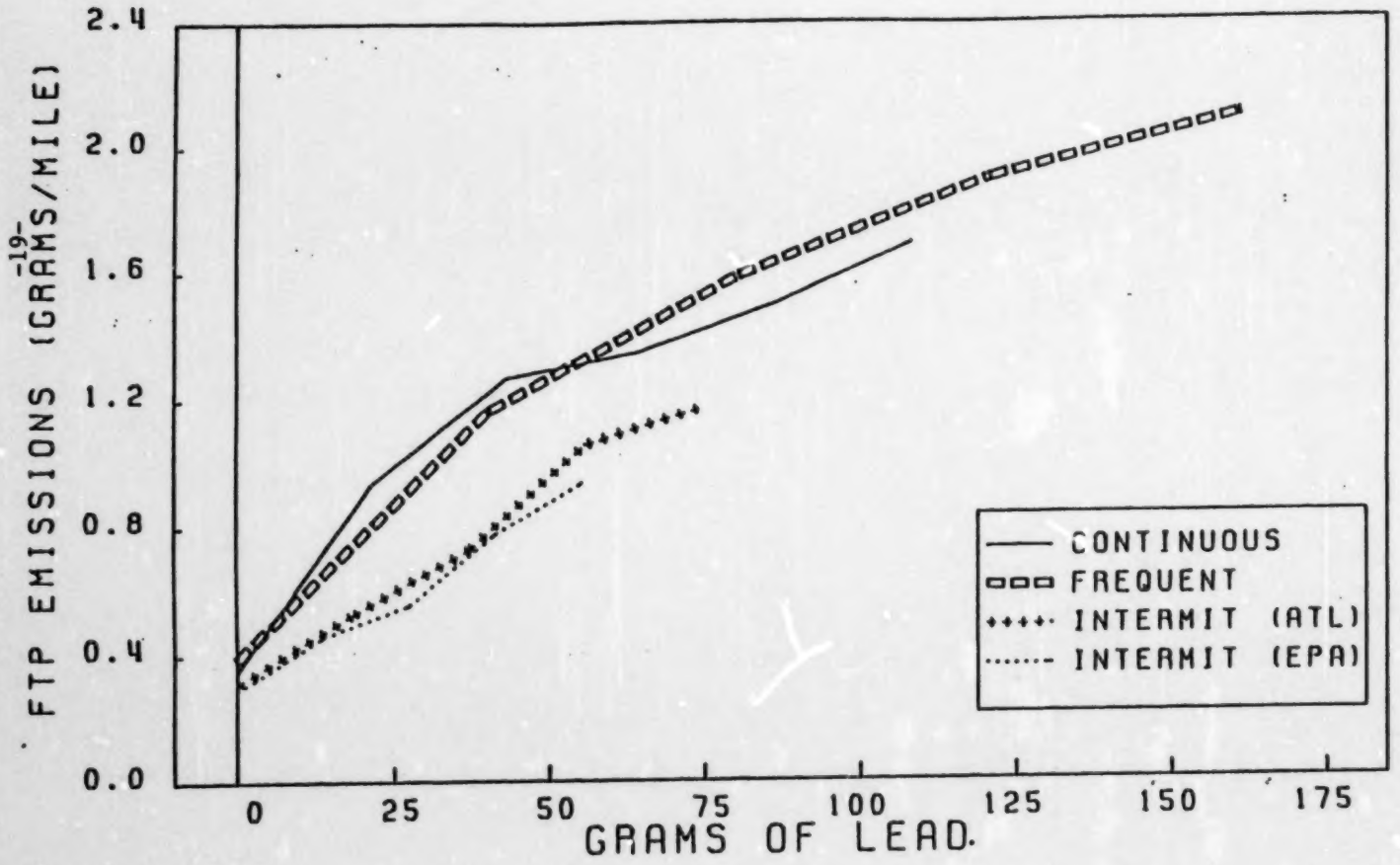

ALTITUDE COMPARISON - HC
FTP HC
2.4
2.0
1.6
1.2
0.8
0.4
0.0
0.37
1.70
2.04
0.48
1.29
1.88
LOW ALTITUDE
HIGH ALTITUDE
BASELINE
MISFUELED (10)
NO CATALYST

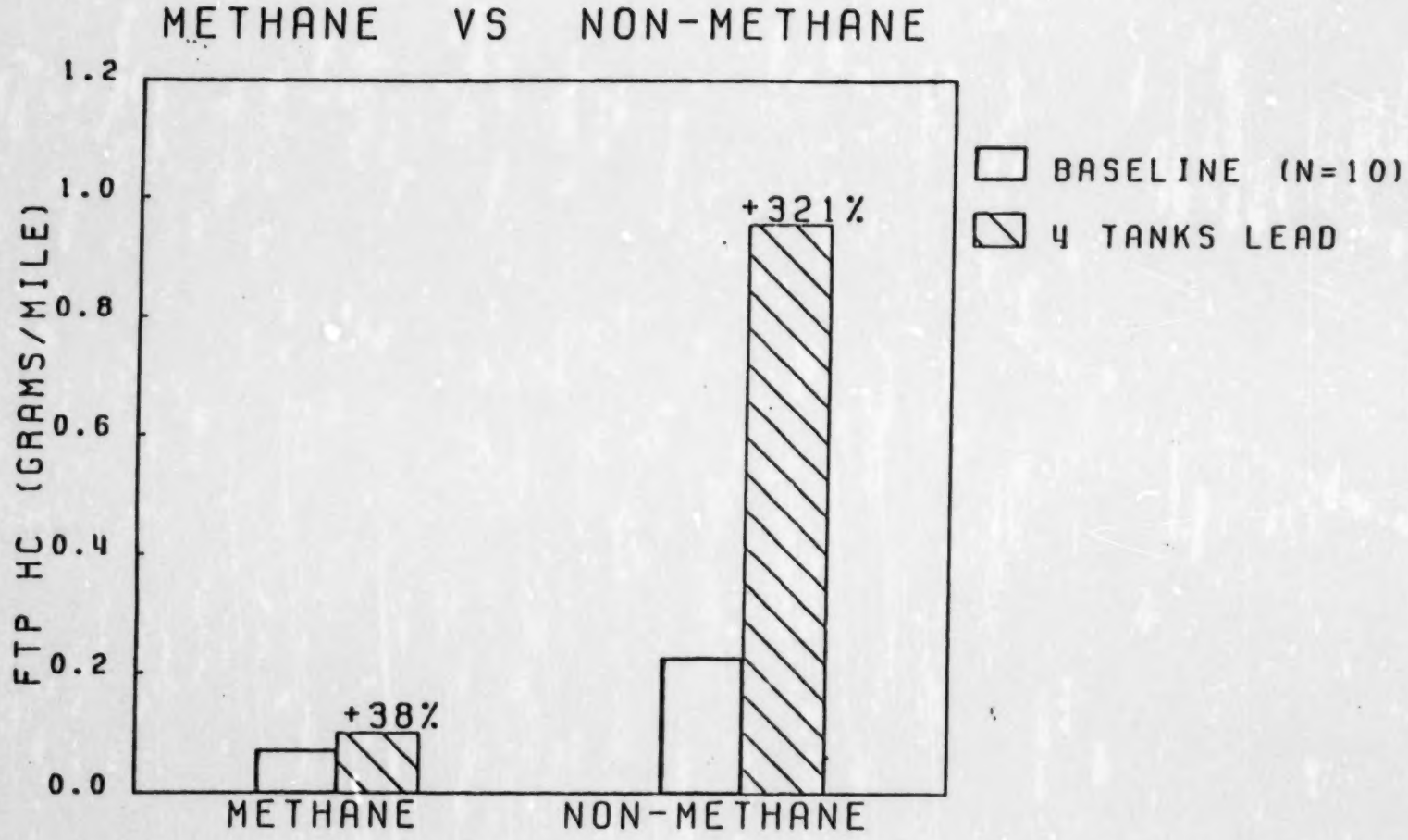

ALTITUDE COMPARISON - CO
FTP CO
30
25
20
15
10
5
0
4.7
15.3
22.2
8.4
14.9
25.9
LOW ALTITUDE
HIGH ALTITUDE
BASELINE
MISFUELED (10)
NO CATALYST


ALTITUDE COMPARISON - NOX
FTP NOX
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.70
1.32
2.87
0.89
1.76
3.42
LOW ALTITUDE
HIGH ALTITUDE
BASELINE
MISFUELED (10)
NO CATALYST


HC VS TANKS OF LEAD
FTP EMISSIONS (GRAMS/MILE)
2.4
2.0
1.6
1.2
0.8
0.4
0.0
0
2
4
6
8
10
12
14
TANKS OF LEAD
CONTINUOUS
FREQUENT
INTERMIT (ATL)
INTERMIT (EPA)

HC VS GRAMS OF LEAD




METHANE VS NON-METHANE
FTP HC (GRAMS/MILE)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
+38%
+321%
METHANE
NON-METHANE
BASELINE (N=10)
4 TANKS LEAD

ADDITIONAL CATALYST CHECKS

- CATALYST SKIN TEMPERATURE MEASUREMENTS
- SHORT TESTS WITH SPARK PLUG DISCONNECTED
- LOADED SHORT TESTS AT VARIOUS SPEEDS
- TRANSIENT LOADED SHORT TEST
- GAMMA RAY LEAD MEASUREMENTS